ARBUCKLE & STAHL

# Impact Tests on Bolts

Mechanical Engineering

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# IMPACT TESTS ON BOLTS

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IN

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

George Samuel Arbuckle and Ambrose Carl Stahl

ENTITLED Impact Tests on Bolts

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in

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# IMPACT TESTS ON BOLTS

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# IMPACT TESTS ON BOLTS

## INTRODUCTION:-

The field of impact tests on bolts is a very large one, and in the short time devoted to a thesis of this sort it is possible to carry out only a few of the tests that might be made. For example, it was planned to make tests on bolts with square threads as well as "v" threads, but there was not time to do so.

An attempt was made to make a series of so-called rebound tests. In these tests it was attempted to collect data showing the amounts of energy absorbed by bolts of different sizes and with different kinds of threads within the elastic limit of the material. It was found that values of the energy absorbed by specimen could not be found with a high degree of accuracy but this did not prevent the finding of relative values which are of considerable importance.

The attempt to find the amounts of energy absorbed in breaking by tensile impact the various sizes of bolts and various kinds of threads was successful as the data will show later.

## THEORY OF IMPACT TESTS:-

The amount of energy delivered by a falling weight (neglecting friction) can be readily calculated from the laws of kinetic and potential energy. However the amount of energy absorbed by a specimen stressed by a falling weight is not such a simple matter, for the apparatus for holding the specimen always absorbs part of the energy, due to its elasticity

and inertia. However this does not prevent obtaining fairly accurately the relative energies absorbed by the various sizes of specimen under the blows of a given weight.

The velocity with which a body falls may be calculated by use of the laws of falling bodies. It is known that $v^2 = 2\ gs$, where v equals the velocity in feet per second, g equals the acceleration due to gravity (neglecting friction), or 32.2 feet per second per second, and s equals the space in feet passed through by the body. The space through which the body falls can be readily measured.

In the rebound tests herein described for stresses within the elastic limit of the material the rebound of a falling weight theoretically should equal the height of its fall, if the specimen and the apparatus holding it are perfectly elastic, but such is not the case and the rebound is only equal to a small part of the actual drop, due to friction of the falling weight, inertia of the apparatus holding the specimen and the material not being perfectly elastic.

In the rebound tests the height of drop in inches was used as ordinates and plotted against the height of rebound in tenths of inches used as abscissae. It was thought that these curves would show a decided bend at the elastic limit of the material under impact. Upon calculation (which will be given below) it was found that the fifty pound weight would need to fall less than one half inch to exceed the elastic limit of a one half inch bolt four inches long. The following are the calculations for the resilience of a one half inch specimen four inches in length stressed to the elastic limit. $K = \frac{1}{2}(S^2/E)\ al$, where K equals elastic resilience of the specimen, S equals tensile stress at

the elastic limit and will be taken as 40 000 pounds per square inch, E equals modulus of elasticity or 30 000 000, a equals the cross-section in square inches and 1 the length in inches.

$K = \frac{1}{2}( 40\ 000^2/ 30\ 000\ 000)\ \frac{1}{2}^2 \times .7854 \times 4 = 20.94$ inch pounds. If the fifty pound weight is dropped one inch fifty inch pounds are developed. Therefore the fifty pound weight needs to drop (20.94/ 50.) = 0.42 inches to equal the elastic limit of the material. For a one inch specimen the weight must fall four times as far as for the one-half inch ones or 1.67 inches. The degree of refinement of the apparatus is not such as to warrant the accuracy of the results for such a small drop, and consequently little stress can be laid on these tests.

The amount of energy absorbed in the breaking tests was computed from the velocities obtained from the slopes of the curves made on a revolving drum by a pencil attached to the weight. The height to which the weight was raised was read from a scale on the testing machine. The velocity at any point of the fall was found from the slope of the curve traced by the pencil. A zero line was made on the drum when the weight was resting on the specimen. (Details of operation will be found under the paragraph entitled Description and Operation of Testing Apparatus on page 4.) The slopes of the curves were found as follows, at a distance of one inch from the intersection of the curve and the zero line a perpendicular was erected to the zero line until it intersected the curve above the zero line. The length of this line in inches is the slope of the curve, for the horizontal distance is one inch. The precise method of measuring velocity from the curve would be to draw tangents to the curves and find the slopes of these tangents. For the distance taken , however, the curve and

its tangent are practically coincident. The slope of the curve after the specimen was broken was found in a similar manner by drawing a horizontal line through the point of inflection indicating the rupture of the specimen, then at a distance of one inch from the intersection of this line and the curve, a perpendicular is drawn intersecting the curve at a point below the line. The length of this perpendicular is again the slope of the curve. The calculations are as follows, (See Plate III., page 16.)

Let n = revolutions per minute of the drum.

c = the circumference of the drum.

s = slope of the curve.

Then $\frac{c\ n}{60 \times 12}$ = velocity of drum in feet per second.

$\frac{c\ n}{60 \times 12}\ s$ = velocity of the falling weight. Call this v.

The energy required to break the specimen is the difference in the kinetic energies before and after breaking the specimen, and is equal to $(\frac{w}{g}\ v_1^2) - (\frac{w}{g}\ v_2^2)$, where $v_1$ is the velocity on striking the specimen and $v_2$ is the velocity at the instant of rupture. Of course this energy is not all used in breaking the specimen because of the loss due to the inertia of the apparatus.

The capacity of the impact machine was a serious handicap in the experiments as we were unable to break the one inch machine cut threads and the one inch rolled threads and only two of the three-quarter inch rolled threads.

DESCRIPTION AND OPERATION OF TESTING APPARATUS:-

The impact machine was made in the Purdue University Shops. A detailed description of the machine will be found in the Proceedings of the

American Society for Testing Materials for 1906, page 462. This particular machine is larger than the one described in the journal, having a capacity of 3 000 foot pounds,(a 500 pound weight dropping approximately six feet. The weight which falls and supplies the energy is held between two vertical guides, and is raised by means of an electromagnet and a motor. The weight is released by opening the circuit containing the electromagnet winding. By a system of gears and pulleys a drum is revolved at a practically uniform speed and a pencil point attached to the falling weight makes a record on the drum on whose surface is fastened a sheet of paper. (See cut on page 7.)

Several different methods were used for determining the surface speed of the drum. At first its revolutions were actually counted for a space of one half minute when the weight was released and the counting continued for another half minute.

This method was unsatisfactory because the motor would speed up as soon as the circuit containing the electromagnet was opened. The next method was to count the revolutions for a minute and release the weight, this appeared to give better results. During the latter part of the tests a tachometer was used to register the revolutions of the shaft to which the small bevel gear which drives the drum is fixed. These bevel gears have a gear ratio of three to one, hence the drum makes one third as many revolutions as the shaft from which the tachometer readings are taken.

A special apparatus was designed for holding the bolts for the tests. Detailed drawings of this apparatus are given on page 9 and a photograph on page 8. This apparatus consists of a frame made of nickel-steel slabs, seven and one half inches

wide and two inches thick and two pins made of 1 15/16 inch cold rolled shafting, six inches in length. These pins pass through holes in the cross piece of the frame and rest on a steel plate. The specimen is passed through both the cross piece of the frame and the plate on which the pins rest. The apparatus when so arranged is for testing four inch specimens. When eight inch specimens are tested a block of steel with a hole for the specimen is added below the lower plate, in order to hold the specimen. Holes were countersunk to hold thick washers with different size holes so specimens of different diameters could be tested.

The nuts on the studs were made about as tight as they could be made by hand, so as to avoid any appreciable initial tension.

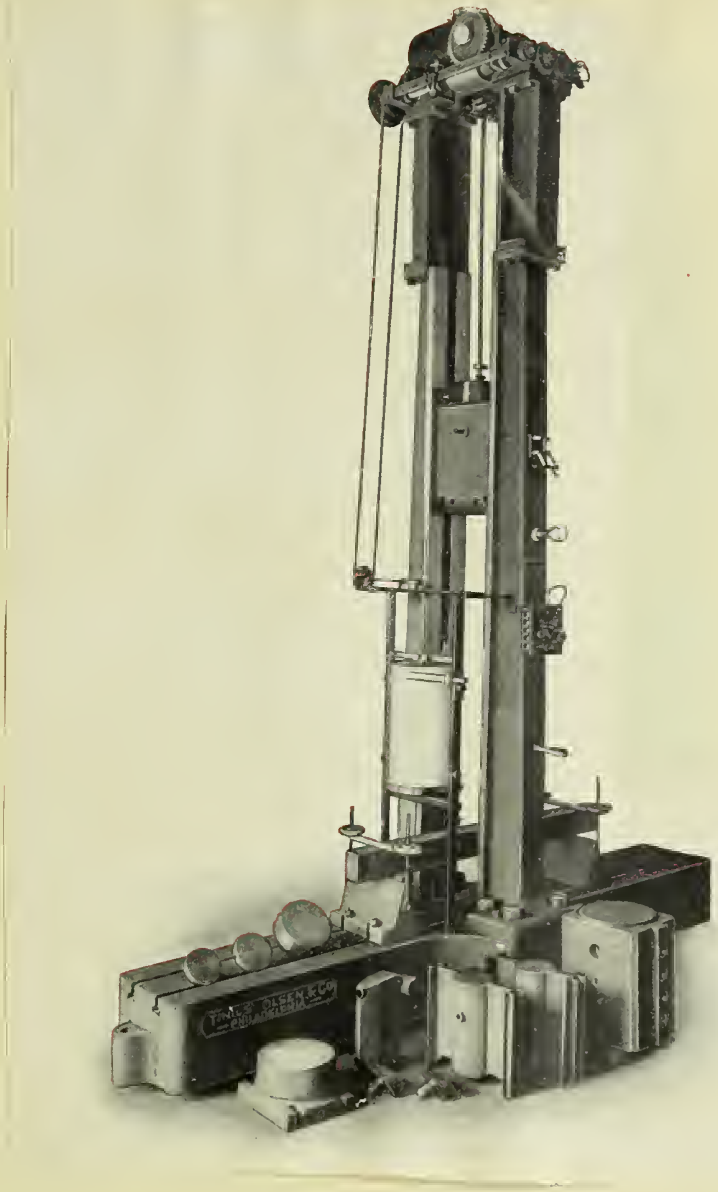
The fifty pound weight was used in the rebound tests.

The five hundred pound weight was used in the breaking tests.

When the fifty pound weight was used in the machine it was necessary to place a heavy slab of steel on top of the pins in order to transfer the impact axially.

Pieces of wood were laid on top the bolt holding apparatus to ease the shocks of the falling weight as it reached the bottom of its fall. Another piece was placed beneath the lower nut to keep it from striking the bed of the machine and battering the threads on the specimen so the nuts can not be readily removed.

Two nuts were placed on each end of the studs in the one half inch and three quarter inch tests.



Turner-Hatt Impact Testing Machine.

Turner-Hatt Impact Testing Machine.

Attachment for Tension Impact Tests of Bolts.

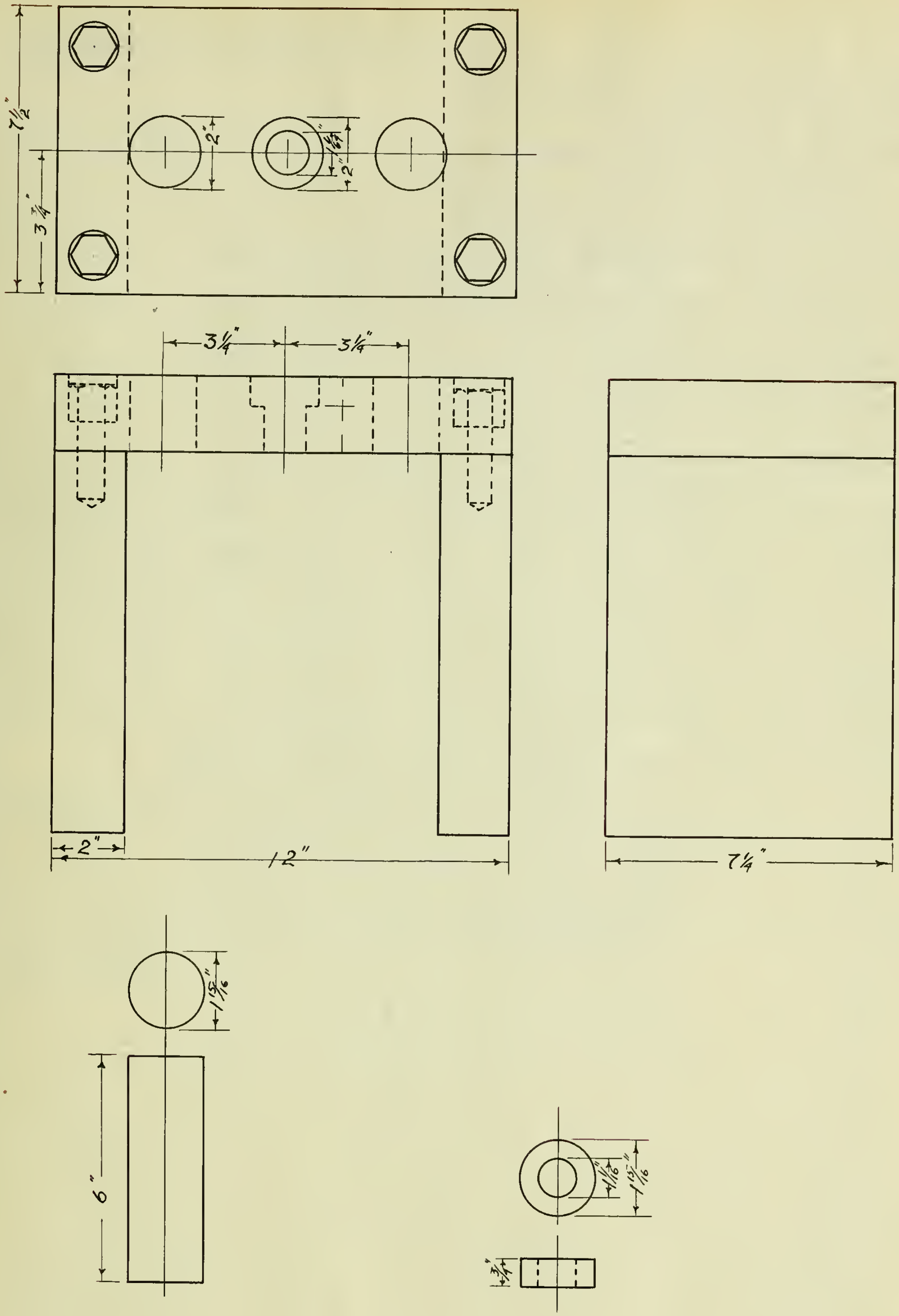



PLATE I.

DESCRIPTION OF TESTS PIECES:-

The specimens were made of soft steel such as would be used in ordinary engineering practice, with the exception of a few specimens one inch in diameter which were made of high carbon steel. The specimens of cut threads were made by the writers on the screw threading machine in the University machine shop. Great care was taken to have the specimens of equal length, the threaded portions were of the same length, and the root diameters were kept constant by the screw threading machine. The over all length of the specimens used in the four inch tests was six inches and they were threaded an inch and three eights from each end. The specimens used in the eight inch tests had an over all length of ten inches and were also threaded an inch and three eigths from the ends.

The rolled threaded specimens were obtained from the Oliver Iron and Steel Works, Pittsburg, Pennsylvania.

All of the specimens of cut threads of the same diameter were made from the same piece of stock in order to insure uniformity.

Table 2

DIMENSIONS OF SPECIMENS
All dimensions in inches

| Kind of Thread | Diameter of Stock | Root Diameter | Over all Length | Length Tested |
|---|---|---|---|---|
| U.S. | 1/2 | 0.42 | 6.0 | 4.0 |
| " | " | " | 10.0 | 8.0 |
| " | 3/4 | 0.62 | 6.0 | 4.0 |
| " | " | " | 10.0 | 8.0 |
| " | 1 | 0.84 | 6.0 | 4.0 |
| Rolled | 0.44 | 0.39 | 6.0 | 4.0 |
| " | 0.69 | 0.61 | 6.0 | 4.0 |
| " | 0.94 | 0.82 | 6.0 | 4.0 |

Some 1/2 and 3/4 specimens were threaded the entire length, these were only four inches in length.

Table 1

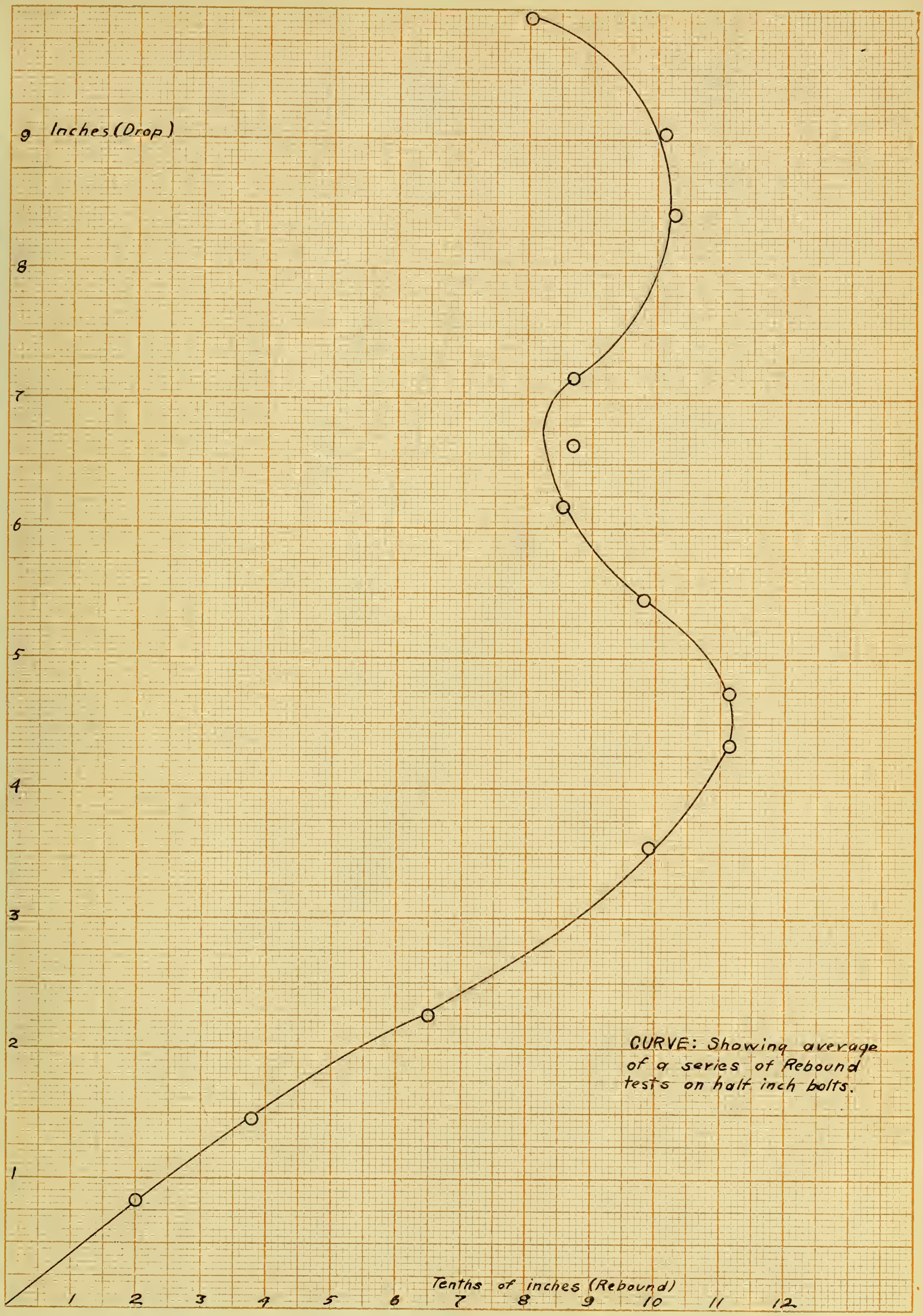
DATA OF TESTS

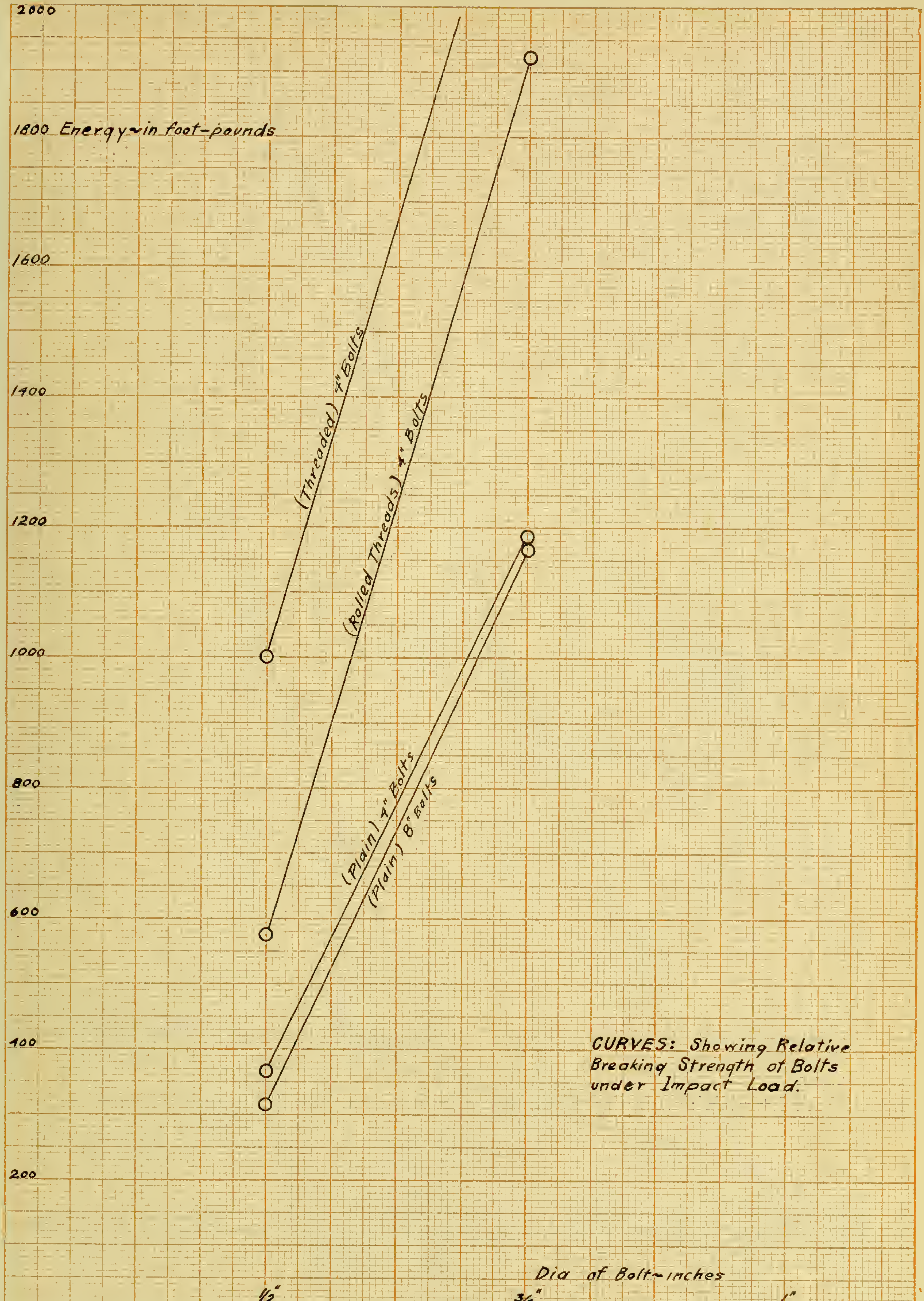
| No. of Test | Material of Bolt | Kind of Thread | Kind of Stock | Dist. Weight Falls Inches | Weight Lb. | Velocity feet per sec. Initial Calculated | Velocity feet per sec. Initial Recorded | Velocity feet per sec. Final Calculated | Foot Pounds Energy Absorbed |
|---|---|---|---|---|---|---|---|---|---|
| | | | | ½" x 4" Bolts | | | | | |
| a1 | Soft Steel | Cut | Plain | 12.1 | 500 | 8.05 | 8.05 | 4.61 | 339. |
| a2 | " | " | " | 12.1 | " | 8.05 | 7.70 | 3.43 | 368. |
| a3 | " | " | " | 12.2 | " | 8.10 | 8.13 | 3.75 | 403. |
| a4 | " | " | " | 12.23 | " | 8.11 | 8.20 | 3.95 | 390. |
| a5 | " | " | " | 12.00 | " | 8.03 | 7.95 | 4.28 | 345 Av.369. |
| | | | | ½" x 4" Bolts | | | | | |
| b1 | " | " | Threaded | 24.00 | " | 11.36 | 10.03 | 2.42 | 955. |
| b2 | " | " | " | 24.00 | " | 11.36 | 10.04 | 2.02 | 970.Av.962. |
| | | | | ½" x 8" Bolts | | | | | |
| c1 | " | " | Plain | 12.15 | " | 8.08 | 7.77 | 4.97 | 314. |
| c2 | " | " | " | 12.05 | " | 8.05 | 7.98 | 4.57 | 341. |
| c3 | " | " | " | 12.00 | " | 8 04 | 7.75 | 4.89 | 314. |
| c4 | " | " | " | 12.15 | " | 8.08 | 8.10 | 5.41 | 279. |
| c5 | " | " | " | 12.25 | " | 8.10 | 7.87 | 5.14 | 306.Av.311. |
| | | | | 3/4" x 4" Bolts | | | | | |
| d1 | " | " | " | 30.1 | " | 12.70 | 11.75 | 4.16 | 1120. |
| d2 | " | " | " | 30.2 | " | 12.72 | 11.65 | 2.98 | 1189. |
| d3 | " | " | " | 30.1 | " | 12.7 | 11.98 | 2.54 | 1204. |
| d4 | " | " | " | 36.0 | " | 13.9 | 13.03 | 5.12 | 1320. |
| d5 | " | " | " | 35.9 | " | 13.9 | 13.47 | 8.03 | 1013. Av. 1169. |

Table 1 cont.

| No. of Test. | Material of Bolt | Kind of Thread | Kind of Stock | Dist. Weight Falls Inches | Weight Lb. | Velocity feet per sec. Initial Calculated | Velocity feet per sec. Initial Recorded | Velocity feet per sec. Final Calculated | Foot Pounds Energy Absorbed | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3/4" x 8" Bolts | | | | | | |
| e1 | Soft Steel | Cut | Plain | 36.1 | 500 | 13.8 | 13.2 | 5.42 | 1272. | |
| e2 | " | " | " | 36.1 | " | 13.8 | 13.47 | 6.73 | 1148. | |
| e3 | " | " | " | 36.5 | " | 13.97 | 12.26 | 6.05 | 1231. | |
| e4 | " | " | " | 36.25 | " | 13.94 | 13.33 | 6.05 | 1224. | |
| e5 | " | " | " | 36.2 | " | 13.92 | 13.43 | 7.65 | 1050. | |
| e6 | " | " | " | 36.25 | " | 13.92 | 13.3 | 6.17 | 1209. | Av. 1189. |
| | | | | ½" x 4" Bolts | | | | | | |
| f1 | " | Rolled | " | 18.00 | " | 9.83 | 8.74 | 1.95 | 563. | |
| f2 | " | " | " | 18.00 | " | 9.83 | 9.3 | 1.19 | 661. | |
| f3 | " | " | " | 18.00 | " | 9.83 | 9.1 | 1.25 | 630. | |
| f4 | " | " | " | 18.00 | " | 9.83 | 8.95 | 5.42 | 394. | |
| f5 | " | " | " | 18.00 | " | 9.83 | 9.22 | 2.16 | 628. | Av. 575. |
| | | | | 3/4" x 4" Bolts | | | | | | |
| g1 | " | " | " | 55.25 | " | 17.2 | 15.8 | 2.42 | 1905. | |
| g2 | " | " | " | 57.00 | " | 17.5 | 15.9 | 2.00 | 1930. | Av. 1917. |

Tests were made on nine more specimens of the last size mentioned failed to break the specimens, though a drop of about sixty inches with the 500 pound was made. This means that 3 000 inch pounds of energy was not sufficient to break the bolts.


Inches (Drop)
9
8
7
6
5
4
3
2
1
CURVE: Showing average of a series of Rebound tests on half inch bolts.
Tenths of inches (Rebound)
1 2 3 4 5 6 7 8 9 10 11 12
U. OF I. S. S. FORM 3


2000
1800 Energy~in foot-pounds
1600
1400
1200
1000
800
600
400
200
(Threaded) 4" Bolts
(Rolled Threads) 4" Bolts
(Plain) 4" Bolts
(Plain) 8" Bolts
CURVES: Showing Relative Breaking Strength of Bolts under Impact Load.
Dia of Bolt~inches
1/2"
3/4"
1"
U. OF I. S. S. FORM 3

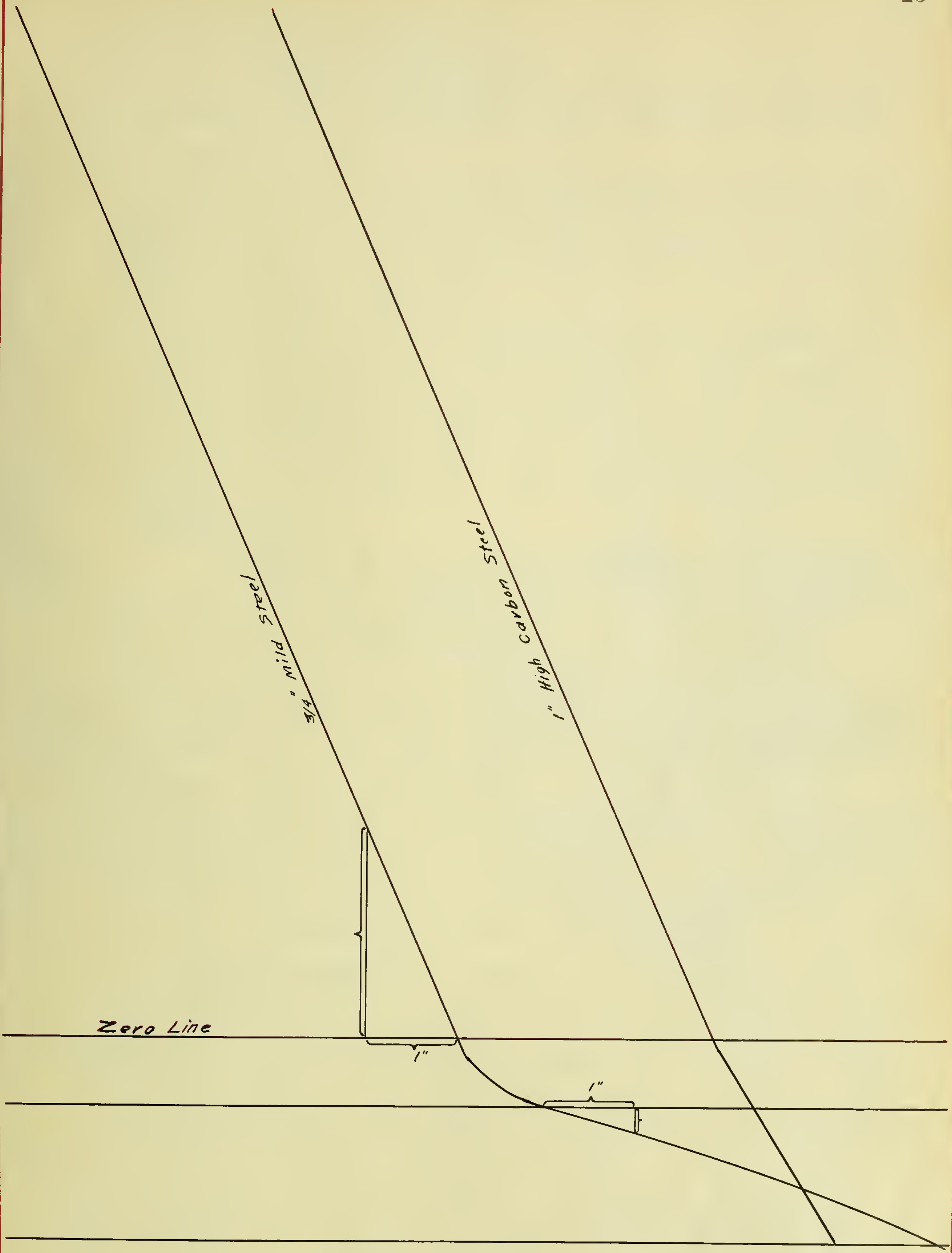



PLATE III

CONCLUSIONS:-

Special emphasis can be laid on the results from the breaking tests. They indicate the following facts (see data on pages 12 and 13.

1. The ratio of the energy absorbed by bolts in tension, due to impact loads, per cubic inch of bolt increases as the diameter of the bolt increases.
2. The energy which can be absorbed by a bolt increases with the relative length of the threaded portion. Bolts threaded the full length absorbed between two and three times the energy absorbed by stud bolts with nuts screwed to the ends of the threaded portion.

   When one of the nuts was screwed up close to the stock the bolt broke more readily than when a few threads were between the nut and the untreaded portion of the stock.
3. Bolts with rolled threads will absorb a little over one and one half times the energy that bolts of the same nominal size with cut threads will absorb.
4. Bolts of high carbon steel which possessing greater resistance to static loads than bolts of soft steel, possess very much less resistance to impact loading. In soft steel bolts the increased amounts of energy required to break the bolts is accompanied by a greatly increased elongation of the bolt.
5. Bolts having long unthreaded shanks absorb about the same amount of energy when broken as bolts having short shanks.